Geophysical Investigations of Earthquake-Induced Liquefaction in the New Madrid Seismic Zone

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Investigations Undertaken

Geophysical surveys were conducted at sites targeted for paleoseismic study in the New Madrid seismic zone (NMSZ). The companion geophysical surveys were designed to 1) locate liquefaction features that might provide critical evidence for constraining the dates of prehistoric earthquake-induced liquefaction events, 2) determine the size, distribution and orientation of ground failure features, and 3) determine the site characteristics, such as physical properties of sediments and associated sediment distributions, that might contribute to the liquefaction susceptibility of an area.

Under this grant award, five (5) sites have been investigated in coordination with paleoseismic studies conducted by M. Tuttle (University of Maryland), R. Lafferty (Mid-Continental Research Associates, M. Haynes (Blytheville, Arkansas), and E. Schweig (USGS). These sites are located near the municipalities of Steele and Wyatt, Missouri, Marked Tree, Arkansas, and Blytheville, Arkansas (Figure 1). The principal geophysical methods used were electromagnetic, magnetic and electrical resistivity. All but two of the sites were surveyed with geophysical methods prior to the paleoseismic excavation. Maps of geophysical anomalies were used in combination with soil characteristics and artifact distribution to identify specific locations for trenching. Trenches were sited at places thought to have both buried liquefaction features and Native American occupation horizons. The latter have proven useful for constraining ages of the liquefaction events (see Tuttle and Schweig, 1996; Lafferty, 1996; Collier et al., 1997).

Results

Three (3) of the sites investigated (Dodd, Brooke and Hillhouse) were discussed previously in the 1998 annual report to NEHRP. For information on these sites, the reader is referred to Wolf et al. (1999), Tuttle et al., 1999, and Collier (1998). The remaining 2 sites are described below.

The Walker Site: The Walker site, located in Marked Tree, Arkansas, was selected for paleoseismic study based on the presence of weathered sand blows, a large Native American mound, and abundant artifacts. Surface reconnaissance was followed by geophysical surveys to identify optimal locations for trenching. Two survey grids were created: one encompassing the north and west sides of the mound, and the other covering an area to the south of the mound. Prominent geophysical anomalies were observed in the electrical and electromagnetic data from both survey grids, indicating the presence of large, northwest-southeast trending sand blows and associated dikes on the west and south sides of the mound (Figure 2). In the northwest corner of the survey grid, high resistivity values indicated the presence of a sand deposit (probably a sand blow), but the area had a low artifact density and was therefore rejected for further study. Magnetic surveys were performed to identify possible locations of buried occupation horizons and cultural features that might be useful in constraining the age of the liquefaction features. Despite having a high surface concentration of artifacts, the area to the north of the mound was rejected for paleoseismic investigation because it lacked a strong indication of buried liquefaction features. This interpretation was derived from the geophysical surveys and small soil test pits. Based on the geophysical results, artifact concentration, and soil characteristics, the west and south sides of the mound were determined to be the most promising for further study.

Three trenches (two on the west side and one on the south side) were excavated across geophysical anomalies (Figure 2). In one trench on the west side, a fine to medium grained northwest trending sand dike crosscut black, silty clay soil horizons containing pottery sherds, charcoal, deer bones, and a few points (Figure 3). Host material on the south side of the dike was displaced downward 15 cm relative to that of the north side, and overlain by a sand deposit interpreted to be a sand blow. Artifacts of the Mississippian cultural period were found in the horizon below the sand blow, suggesting that the site was occupied by Native Americans close to the time of the liquefaction event. Radiocarbon dating of charcoal from this horizon indicated that it was buried by the sand blow soon after A.D. 1420-1500. In the other trench on the west side (not shown), the sand blow thinned out, and excavation was abandoned. The third trench, located in the south grid, was again oriented approximately perpendicular to a northwest-trending anomaly observed in the geophysical data. The trench exposed two northwest-trending dikes that crosscut soil horizons. Both dikes contained clasts of host material. Host material between the dikes was vertically displaced 9 cm and was overlain by a sand deposit. A few artifacts were found below the sand blow.

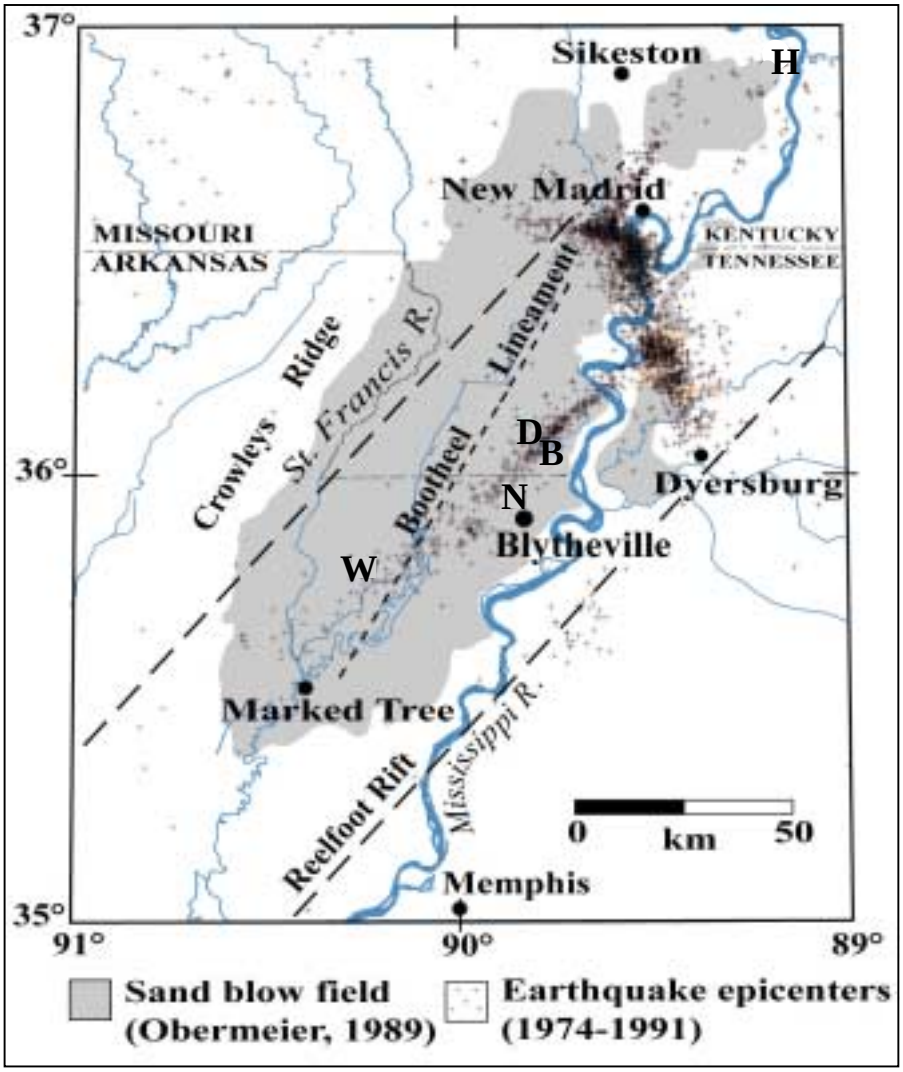

Figure 1. Study locations within the New Madrid seismic zone. W=Walker site (Marked Tree, AR); N=Haynes-4 site (Blytheville, AR); D=Dodd site (Steele, MO); H=Hillhouse site (Wyatt, MO); B=Brooke site (Steele, MO) (modified from Barnes et al., 1999).

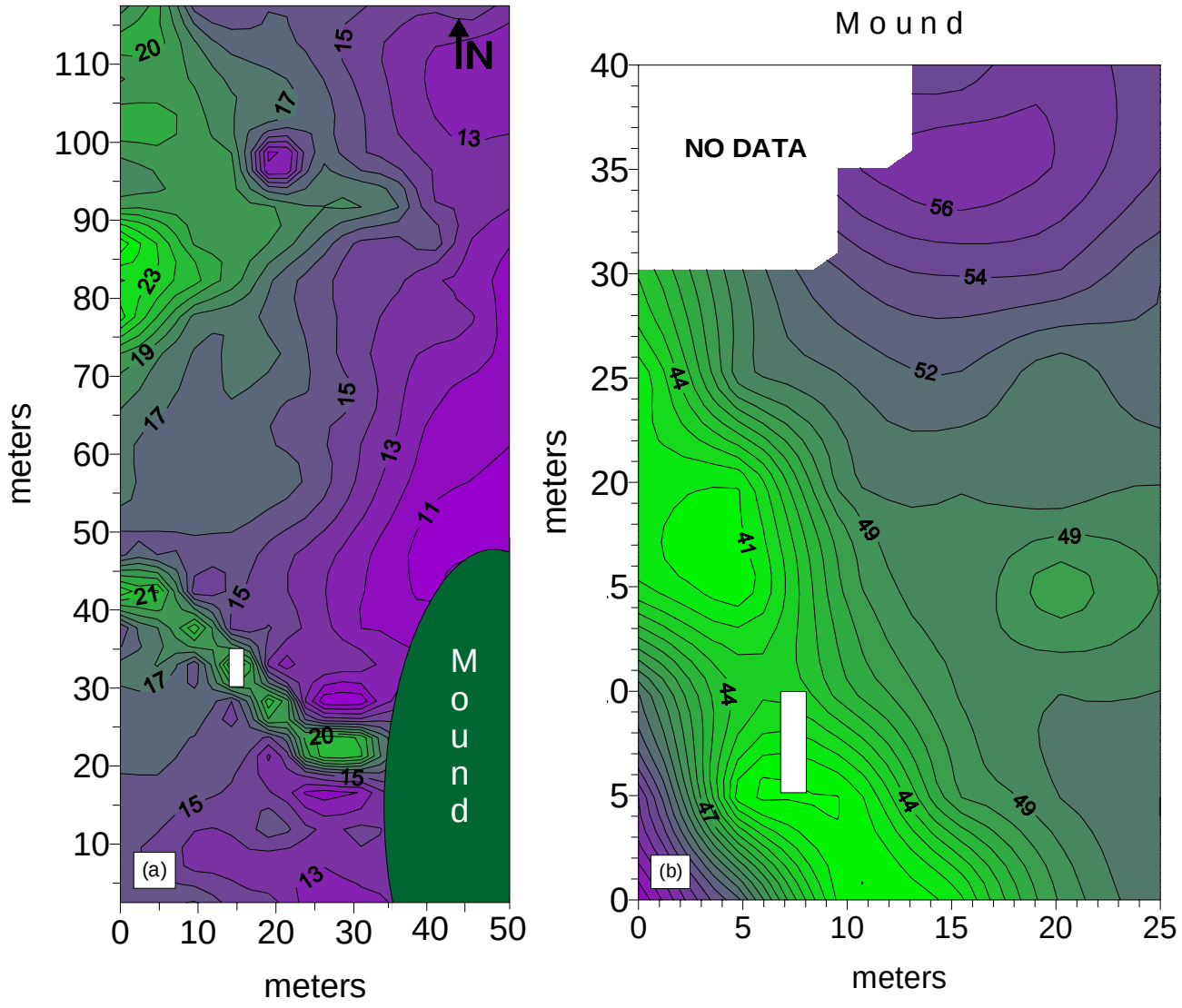

Figure 2. Results of the resistivity and conductivity surveys at the Walker site. (a) Resistivity (in ohm-m) from the survey grid located to the north and west of a Native American mound. High values indicate the presence of a NW-trending sand blow and associated sand dikes. (b) Ground conductivity (in m/mS) from the survey grid located to the south of the mound. Low conductivity values indicate the presence of a NW-trending sand body (blow and associated dikes). Although the orientation of the liquefaction features found in both areas is similar, the features appear to be offset from one another, forming an en echelon failure pattern. Trench positions are noted by rectangles and are oriented perpendicular to the NW-trending geophysical anomalies (from Barnes et al. 1999).

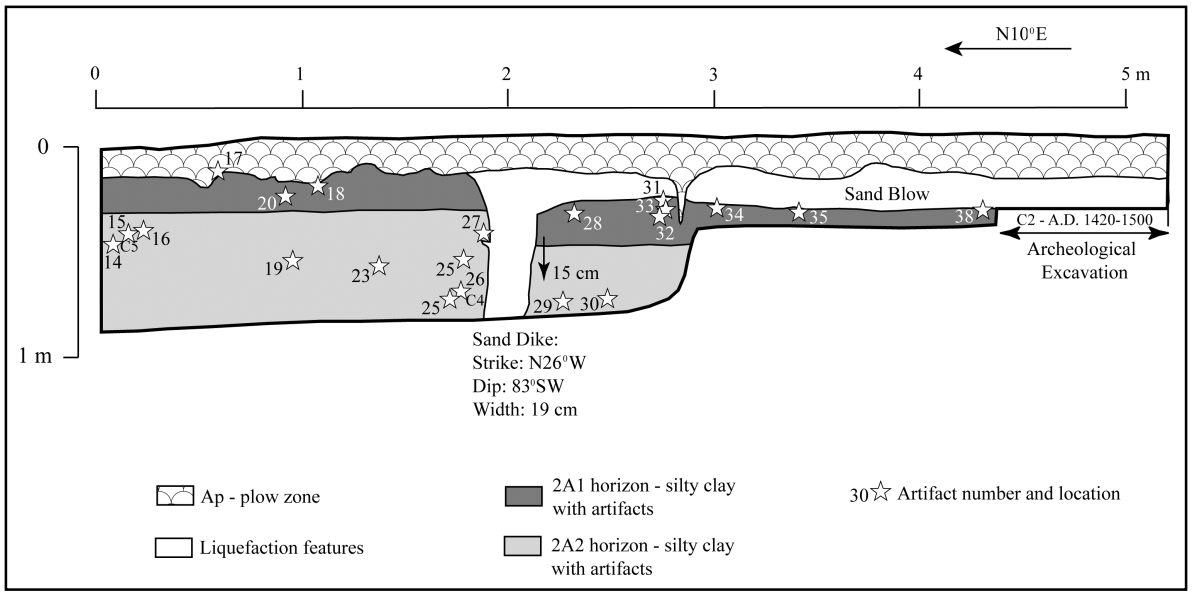

Figure 3. Trench log from the west survey grid at the Walker site (see Figure 2a). Cross-section shows the east wall of the trench. A fine to medium grained northwest trending sand dike crosscuts black, silty clay soil horizons containing pottery sherds, charcoal, deer bones, and a few points. Radiocarbon dating of sample C2 collected from the occupation horizon immediately below the sand blow suggests that it formed soon after A. D. 1420. Artifacts buried by the sand blow suggest that the liquefaction event formed during the Middle or Late Mississippian cultural period (from Barnes et al. 1999; Trench log supplied by M. Tuttle; see Tuttle, NEHRP Annual Report Summary, 2000).

The Haynes-4 Site: At the Haynes-4 site, located near Blytheville, Arkansas, earthquake-induced liquefaction features were discovered in a newly cleaned drainage ditch (M. Haynes, pers. comm., 1999). Geophysical surveys at this site were used to ascertain the general orientation and size of the features and to gain insight into the nature of ground failure, which appeared to be extensive. The site also provided information that endorsed previous findings on the timing of a major liquefaction event in the area. Electromagnetic and electrical resistivity surveys were performed along a grid located east of the ditch (Figure 4). Results indicate variable thicknesses of sand occur throughout the surveyed area and suggest that the site contains multiple, coalescing sand blows. Only one feeder dike was exposed in the ditch; however, the geophysical surveys suggest that others may occur on the east side of the ditch. Anomalies in the geophysical data appear to trend northeast to east-west, subparallel to the nearby Pemiscot Bayou, which trends approximately east-west on the north side of the site.

One sand blow exposed in the ditch was overlain by a Native American occupation horizon containing Early to Late Woodland and Early Mississippian artifacts. A sand dike, exposed in the ditch floor, crosscut a silty, very fine sand deposit and contained clasts of the host deposit. Above the vent, the sand blow was coarse to medium grained and contained many clasts of underlying deposits. The upper part of the sand blow has been removed by erosion. Away from the vent area, the sand blow comprises three units containing coarse sand, fine sand, and very fine to medium sand. Results of two carbon

samples, one from a root cast dug into the occupation horizon and another taken from the occupation horizon itself, did not provide refinement to the age estimate based on the artifact analysis and stratigraphic relationships. The latter suggest that the liquefaction features formed during the Late Woodland to Early Mississippian transitional period, or approximately A.D. 900.

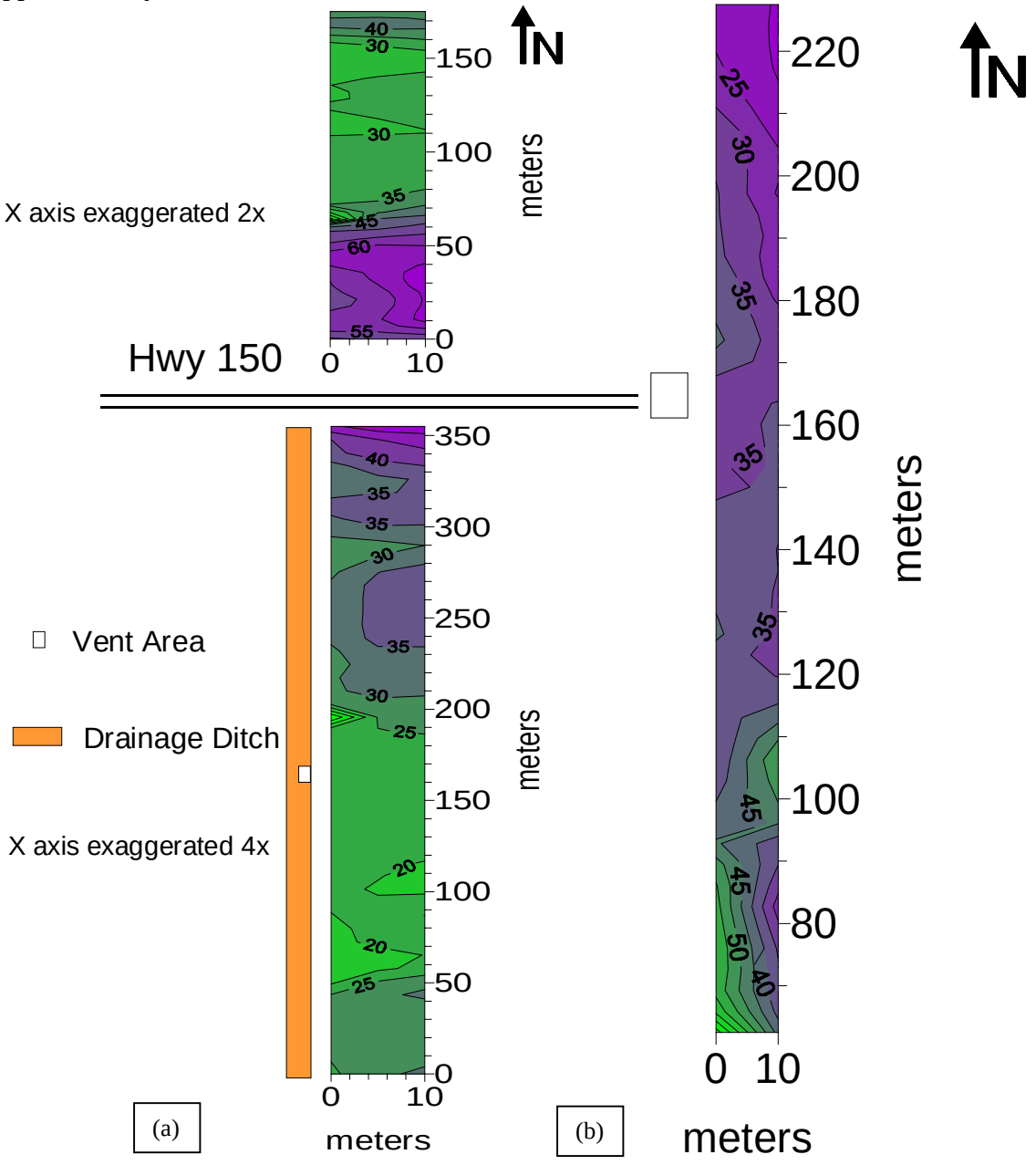

Figure 4. (a) Ground conductivity in m/mS (Note that the scale is exaggerated). Conductivity lows indicate the presence of multiple sand blows; This interpretation was supported by observation in the ditch wall. An exposed sand layer was observed to thin away from the sole feeder dike exposed in the trench. However, at farther distances, the overlying sand layer again thickened, suggesting that this sand might constitute a separate but related sand blow whose source vent was located outside the ditch. (b) Resistivity in ohm-m taken over a small section of the survey grid (from Barnes et al., 1999).

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Non-technical Summary

Geophysical surveys were conducted at five sites in Missouri and Arkansas in conjunction with paleoseismic studies in the New Madrid seismic zone. The surveys were designed to 1) locate buried ground failure features that might provide critical evidence for dating prehistoric earthquakes, 2) determine the size, distribution and orientation of ground failure features, and 3) determine site characteristics that might contribute to the ground failure susceptibility of an area. In addition, the surveys proved to be an effective way to minimize the disruption of culturally sensitive sites. Results will contribute to understanding earthquake-induced ground failure in alluvial environments.